A Multi–Sensor Approach to Monitoring Storm Intensity towards an Application of GOES-R data

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Contributions from

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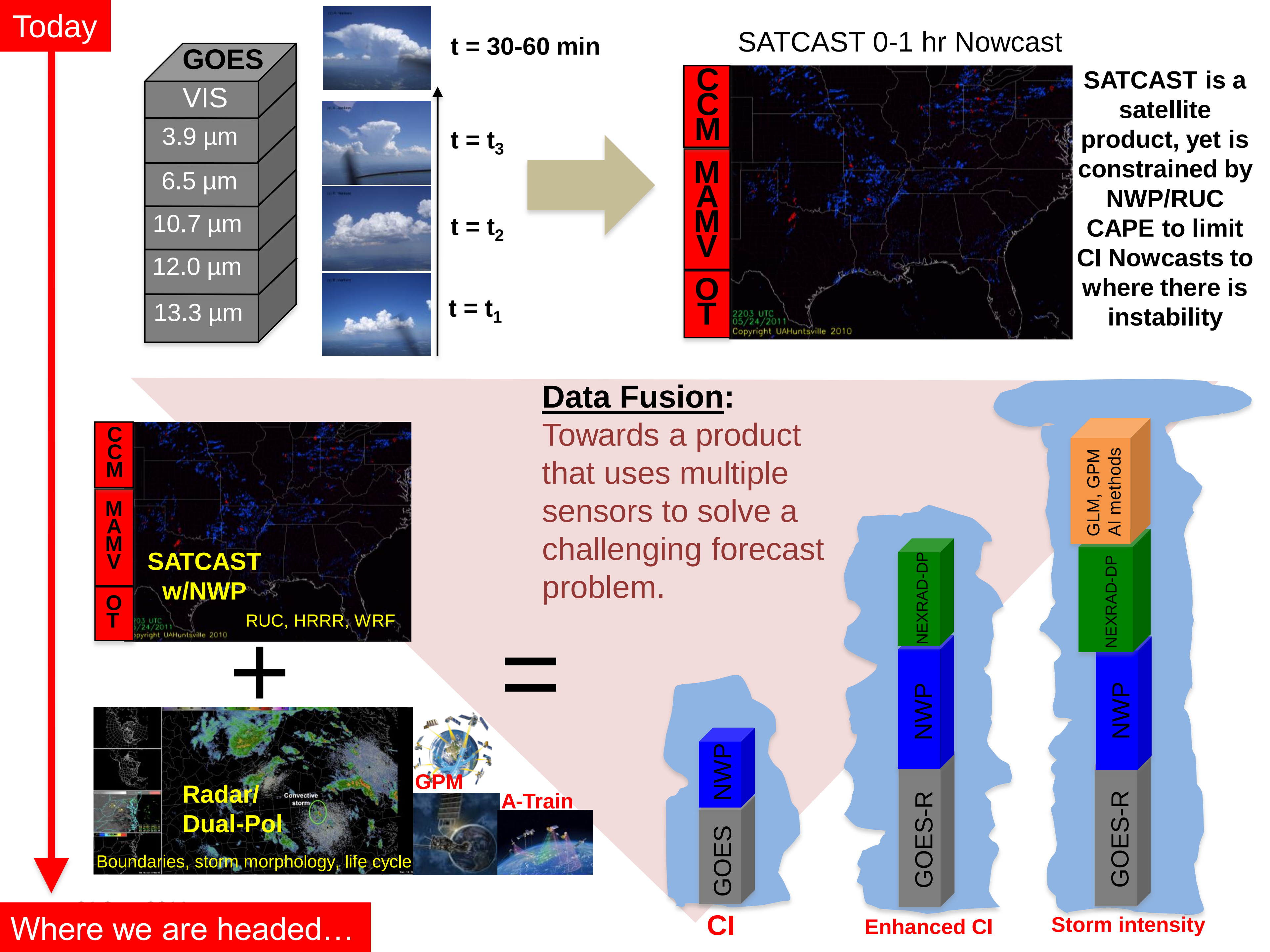
Outline

1. **Update GOES–R Storm Intensity Effort**
   a) Methodology
   b) Progress to date… and ongoing work

2. **Update on “Bake–Off” towards PDSI**


Today
GOES
VIS
3.9 µm
6.5 µm
10.7 µm
12.0 µm
13.3 µm
t = 30-60 min
t = t3
t = t2
t = t1
SATCAST 0-1 hr Nowcast
CCM
MAMV
OT
2203 UTC
05/24/2011
Copyright UAHuntsville 2010
SATCAST is a satellite product, yet is constrained by NWP/RUC CAPE to limit CI Nowcasts to where there is instability
Data Fusion:
Towards a product that uses multiple sensors to solve a challenging forecast problem.
CCM
MAMV
OT
SATCAST w/NWP
RUC, HRRR, WRF
+
=
Radar/ Dual-Pol
Convective storm
Boundaries, storm morphology, life cycle
GPM
A-Train
NWP
GOES
CI
NEXRAD-DP
NWP
GOES-R
Enhanced CI
GLM, GPM AI methods
NEXRAD-DP
NWP
GOES-R
Storm intensity
Where we are headed…

What of these factors to consider towards diagnosing "Thunderstorm Intensity"?

- Proxy GOES-R data will be supplied to this effort from MSG SEVIRI (12 VIS/NIR/IR and 1 HRV channel) and TRMM Lightning Imaging Sensor (LIS) Global Total Lightning Flashes product.

- Utilize established methods that determine the general vigor and strength of active moist convection will be used. These include:
  - Convective cloud identification algorithms (for GOES-R and research)
  - SEVIRI "object tracking" methods
  - Monitoring satellite temporal trends of the spectral channels.
  - SEVIRI IR and Visible data "interest field" research → physical attributes
  - TRMM LIS data
  - Anvil expansion rates (see Shröder et al., 2009)

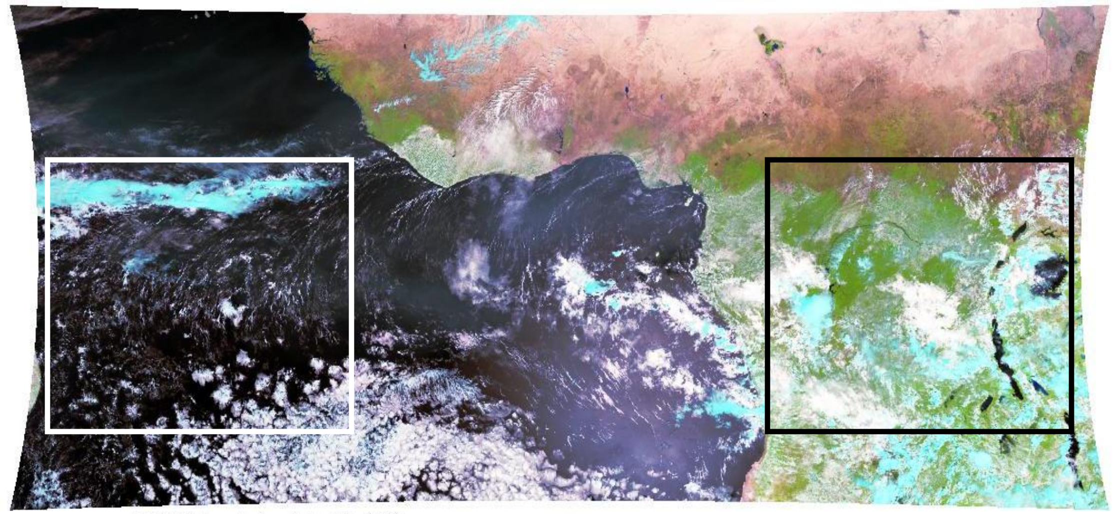
Evaluating storm intensity using coupled TRMM Lightning Imaging Sensor (LIS) and Meteosat Second Generation (MSG) in preparation for GOES-R

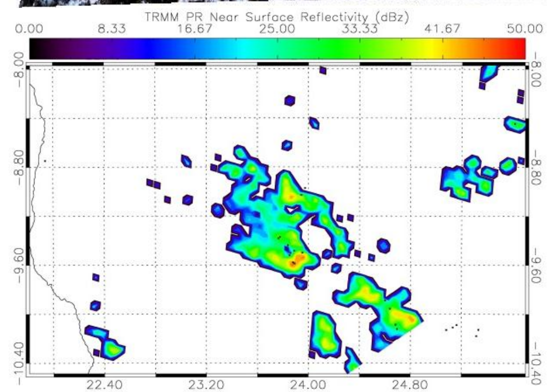
1) Cell identification through storm cell database (LeRoy and Petersen 2011)
2) Storm Intensity as observed by TRMM
3) Observations from TRMM LIS
4) Potential Applications of MSG data
   - Anvil Expansion rates
   - Cloud top cooling rate in growing cumulus
   - Overshooting tops
   - Storm Longevity

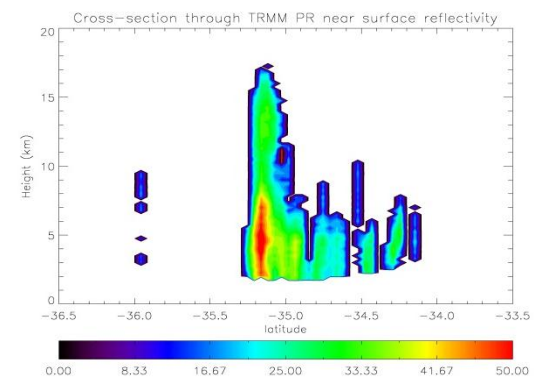
Diagnosing storm intensity using coupled TRMM Lightning Imaging Sensor and MSG in preparation for GOES-R

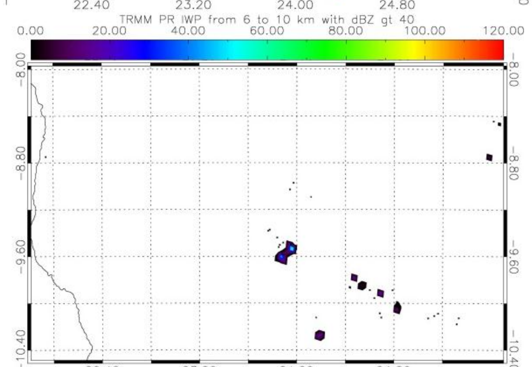
Methodology

- Convective events are first chosen from the precipitation feature database, January and August 2007 over tropical Africa and eastern tropical Atlantic
- Using the storm cell database developed by Leroy and Petersen (2011), analysis of individual storms cells within clusters and isolated can be performed with the benefit of having many different TRMM variables available in one location.
- Storm intensity is determined using the TRMM precipitation radar. Currently, intensity is being defined by the Ice Water Path (IWP) with reflectivities >40 dBz between 6 and 10 km (a mixed phase region important for lightning initiation).
- IWP is calculated for every cell feature over both land and water, making useful statistics when analyzing TRMM LIS and MSG imagery.
- LIS data is converted to flash rates by combining all the flashes for one IWP sample using a nearest neighbor technique and dividing by the average observation time (typically ~90 s).
- MSG data will be collected for each IWP sample time along with an hour of data before and after, allowing for temporal trends of convective interest fields.



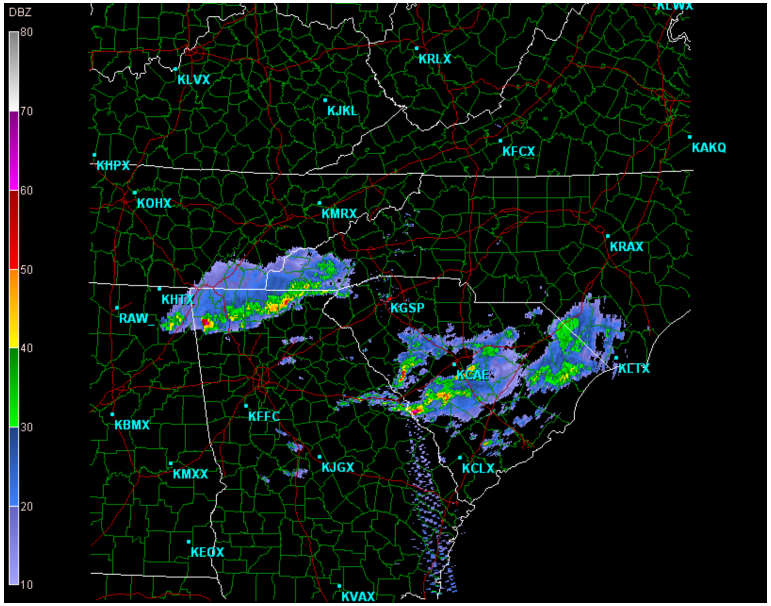




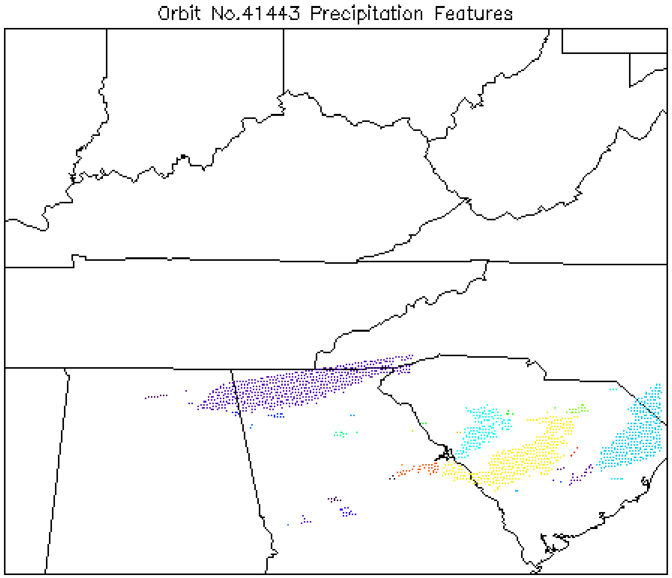


Cell Identification Algorithm: Validation

Begin with TRMM Precipitation Feature Database



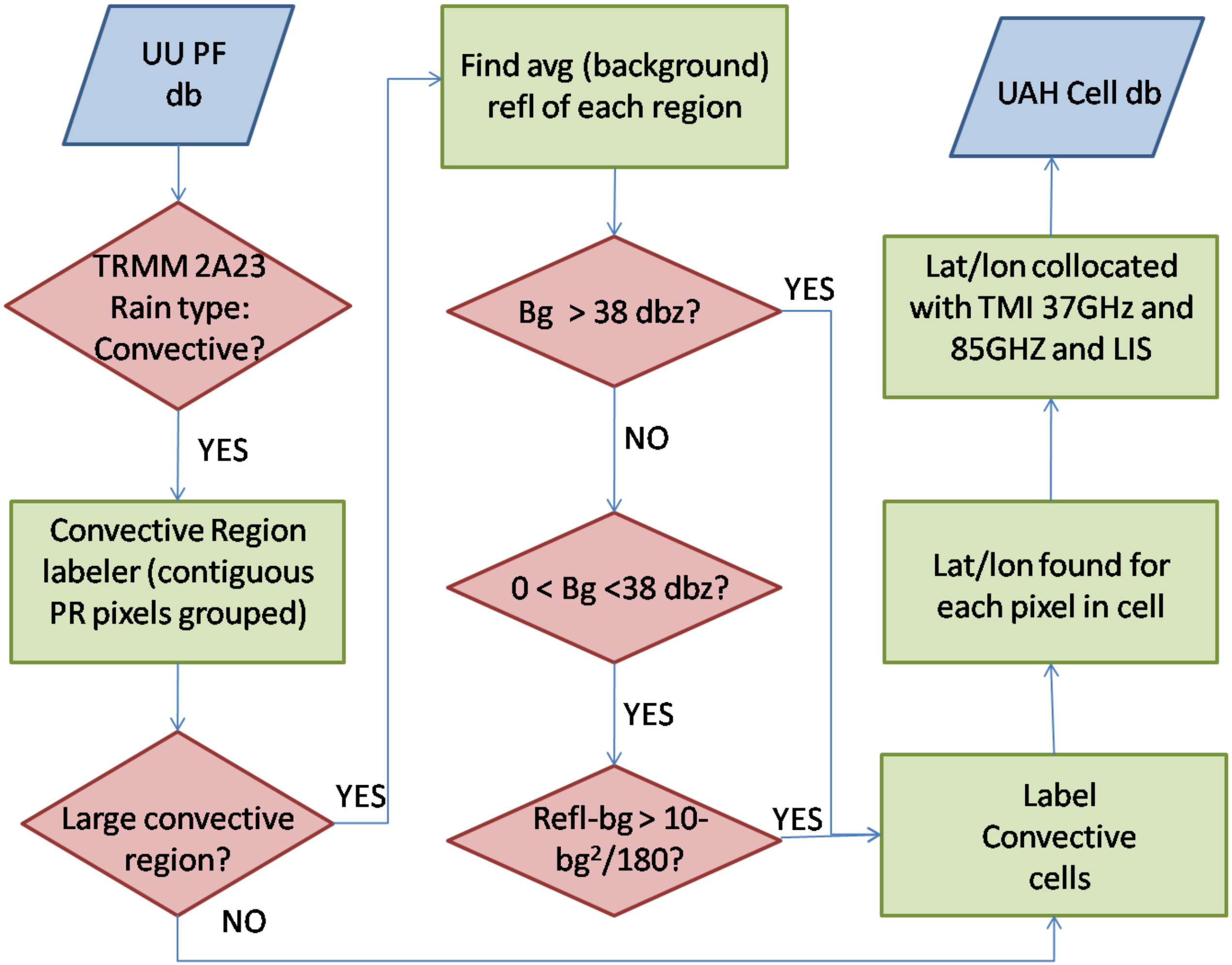
21 February 2005 at 2154 UTC



Each precipitation feature is plotted in a unique color.

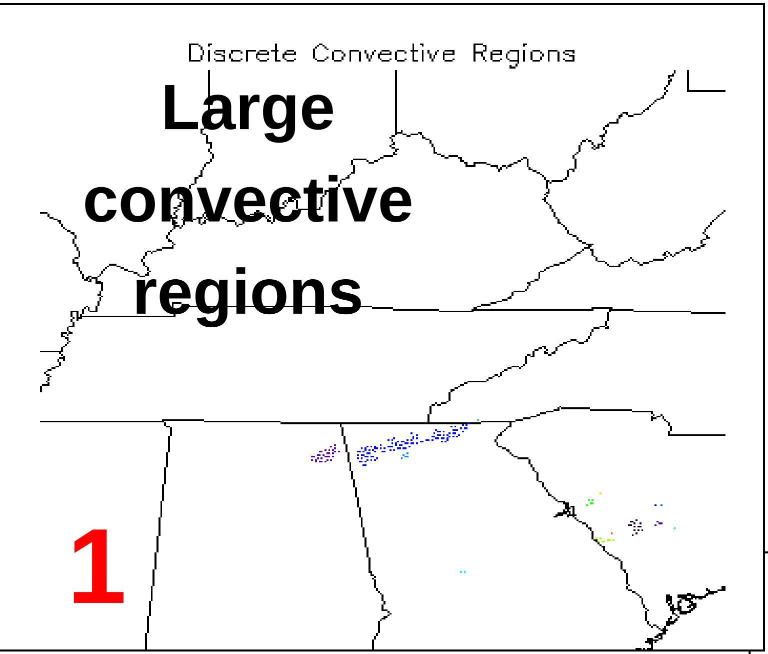
Courtesy: LeRoy (ESSC/UAHuntsville and Petersen (NASA/MSFC)

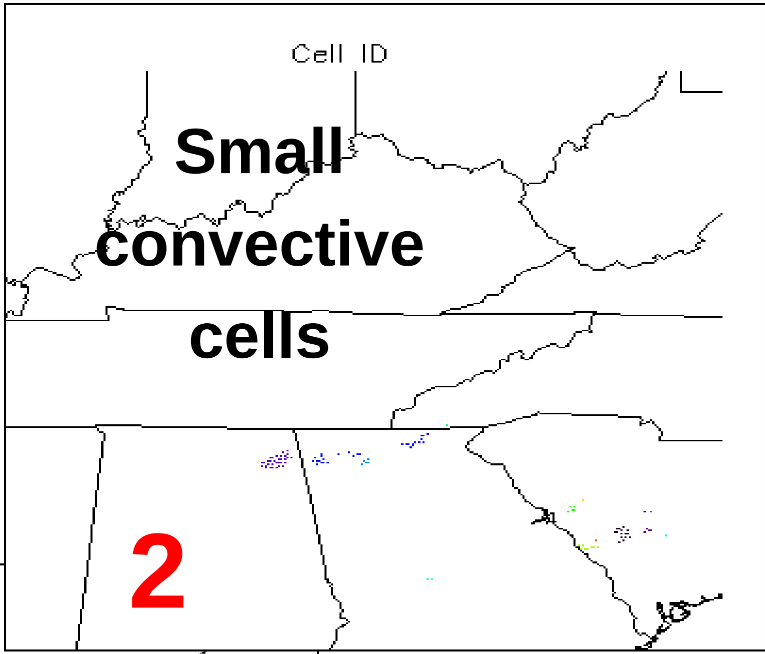
Cell Identification Algorithm

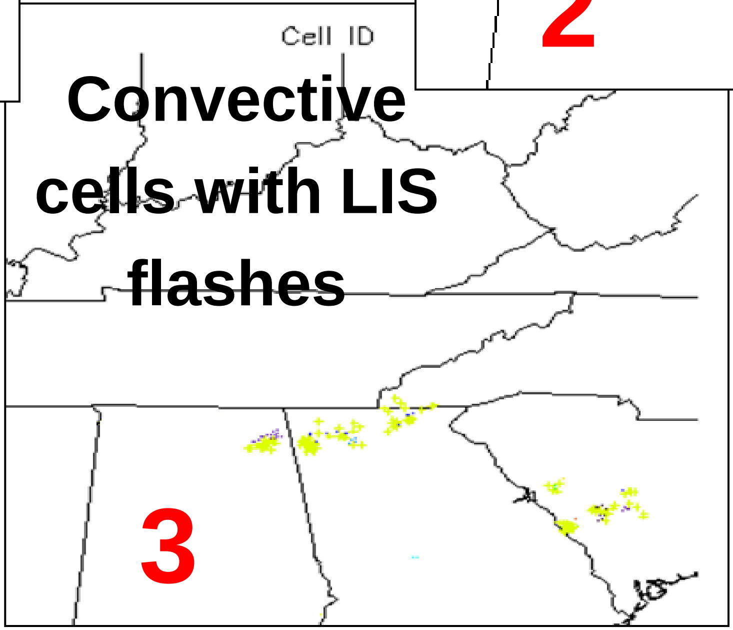


Courtesy: LeRoy (ESSC/UAHuntsville and Petersen (NASA/MSFC)

Cell Identification Algorithm



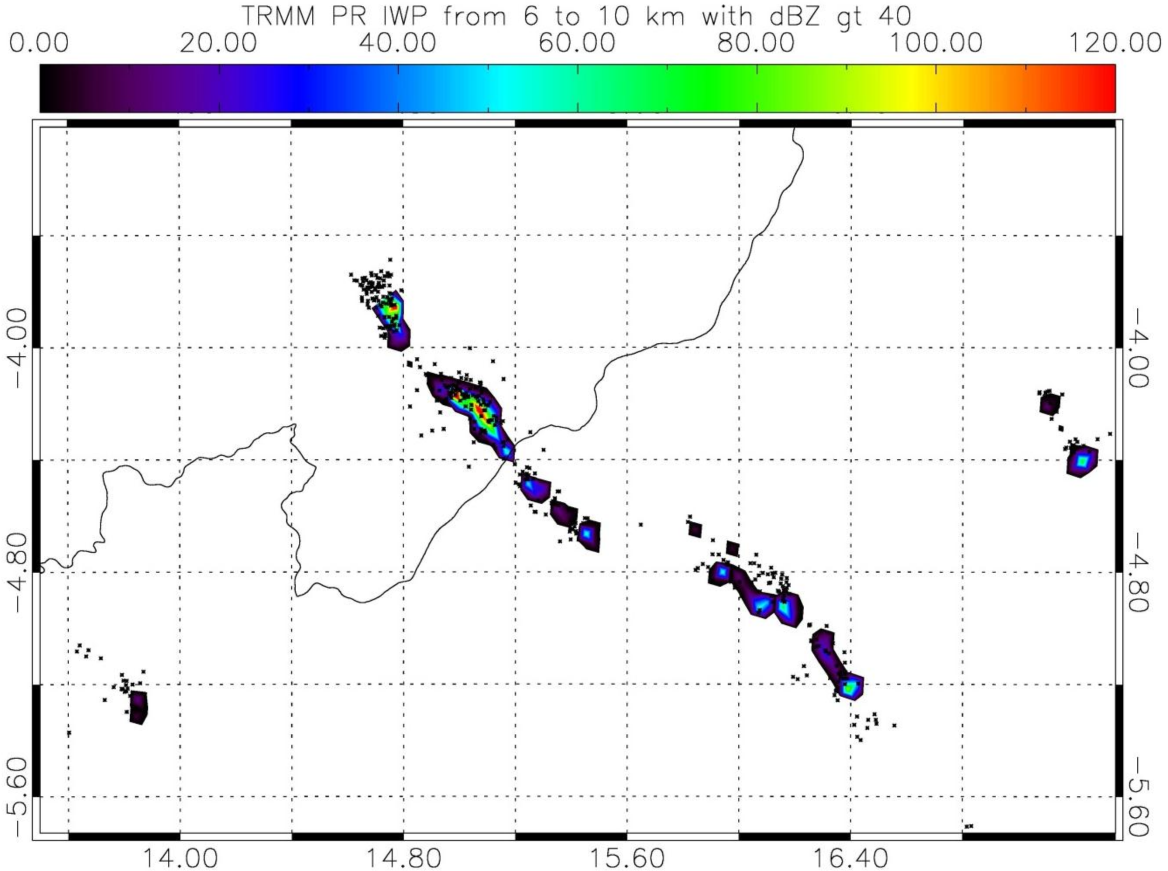




Courtesy: LeRoy (ESSC/UAHuntsville and Petersen (NASA/MSFC)

TRMM Precipitation Radar Storm Intensity

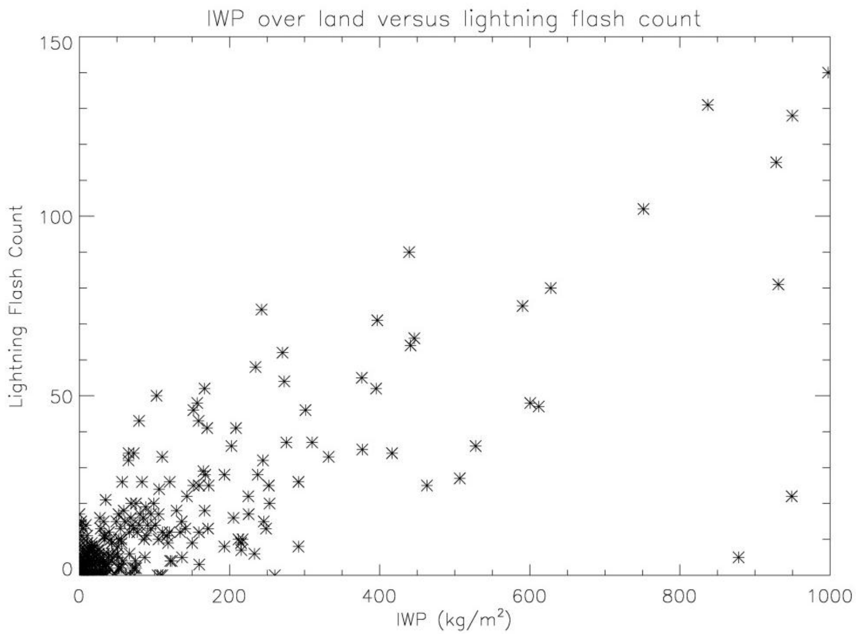
- Currently, intensity is being defined by the Ice Water Path with reflectivities >40 dBZ between 6 and 10 km. This ensures a mixed phase region, which is important for lightning initiation.



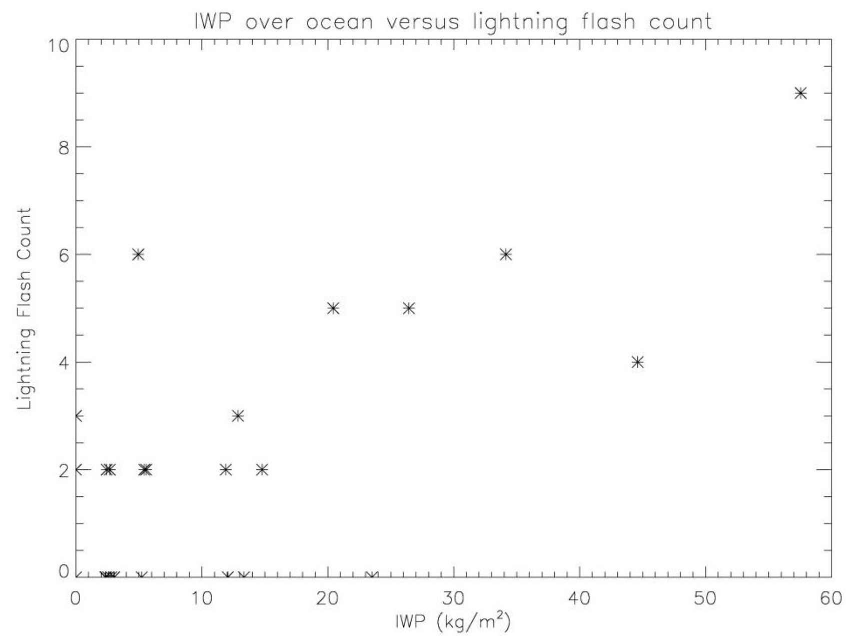
Slightly Intense	Fairly Intense	Moderately Intense	Intense	Very Intense	Extremely Intense
1 - 10	10-50	50-100	100-150	150-200	>200

Lightning flash counts from TRMM LIS

Land



Ocean



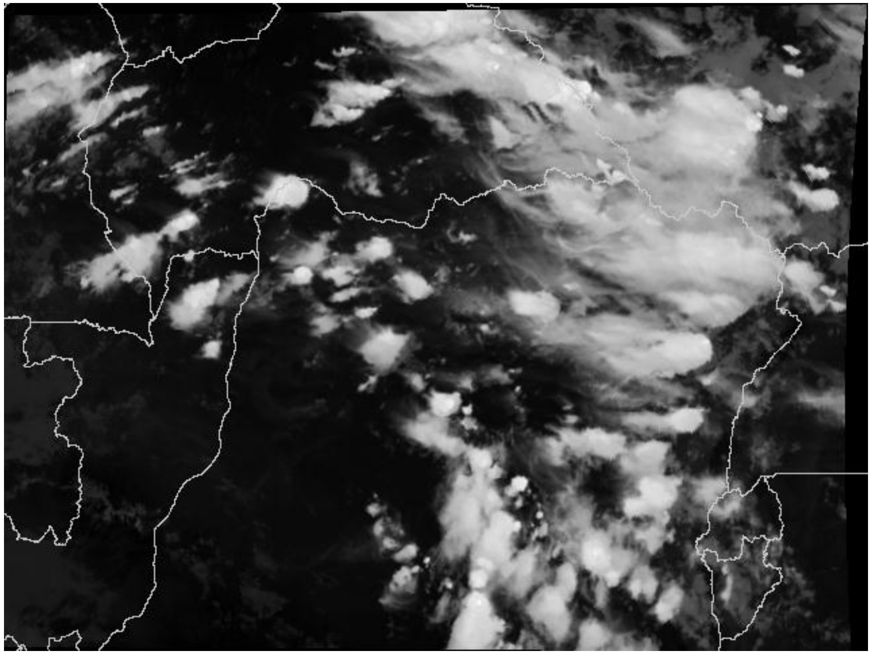
Lightning flash counts correlate well with IWP over land areas due to the microphysics processes encountered over land. Unfortunately over the open ocean, storms do not produce an abundance of lightning due to the increased number of CCN, limiting the amount of charge separation that can occur. However, this does not indicate oceanic convection without or with only minimal lightning cannot be intense.

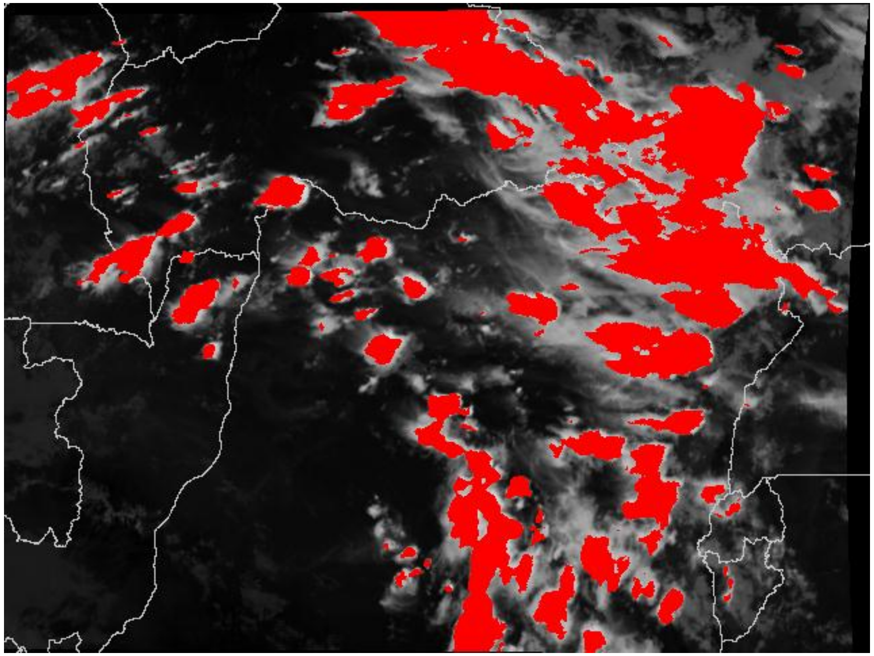
The “truth” for intensity is IWP coupled to lightning flash rates, from TRMM PR and LIS.

Mature Cloud Identification from MSG data

Objects of interest must be identified for further processing and monitoring of intensity.

- 6.2–10.8 µm channel difference can help determine where the cloud is in relation to the mid- to upper troposphere. A small negative difference suggests a cloud near top of the troposphere.
- An “object mask” has been created to locate areas of interest by including all MSG pixels that have a 6.2–10.8 µm difference ≥ –7 K. These objects are assigned unique integer ids and tracked in time through object overlap. If objects overlap between two time periods, the unique integer ID from time 1 is passed onto same object at time 2.

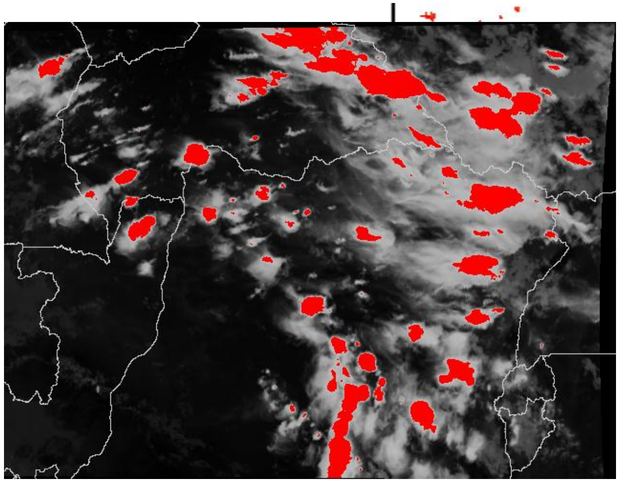




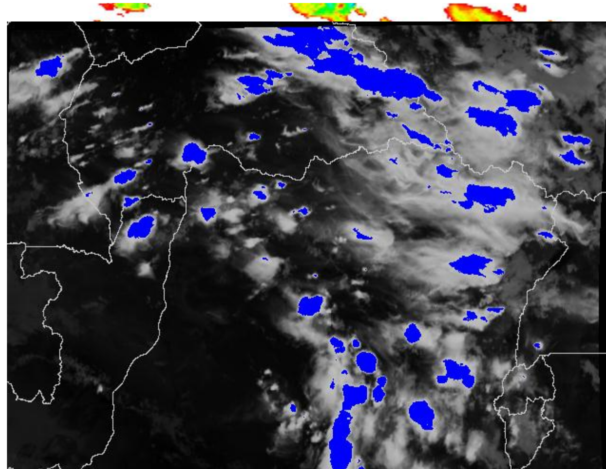
Anvil Expansion Rates

- Anvil expansion rates are related to divergence at the top of the troposphere, which in turn should be directly proportional to updraft strength (Adler and Fenn 1979a).
- The initial 10.8 μm brightness temperature considered is 213 K, which works well for isolated convection. As anvils begin to merge however, the isotherm considered drops to 208 K and will continue to drop until each convective updraft has a separate brightness temperature.
- Here we show the mature object worth monitoring for intensity.

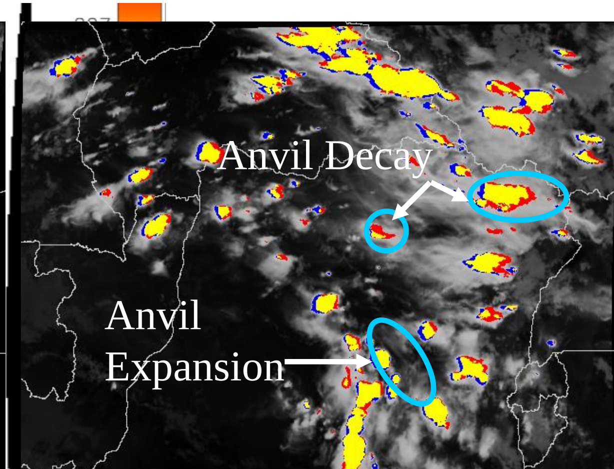
TB ≤ 213 K at 1627 UTC



TB ≤ 213 K at 1642 UTC

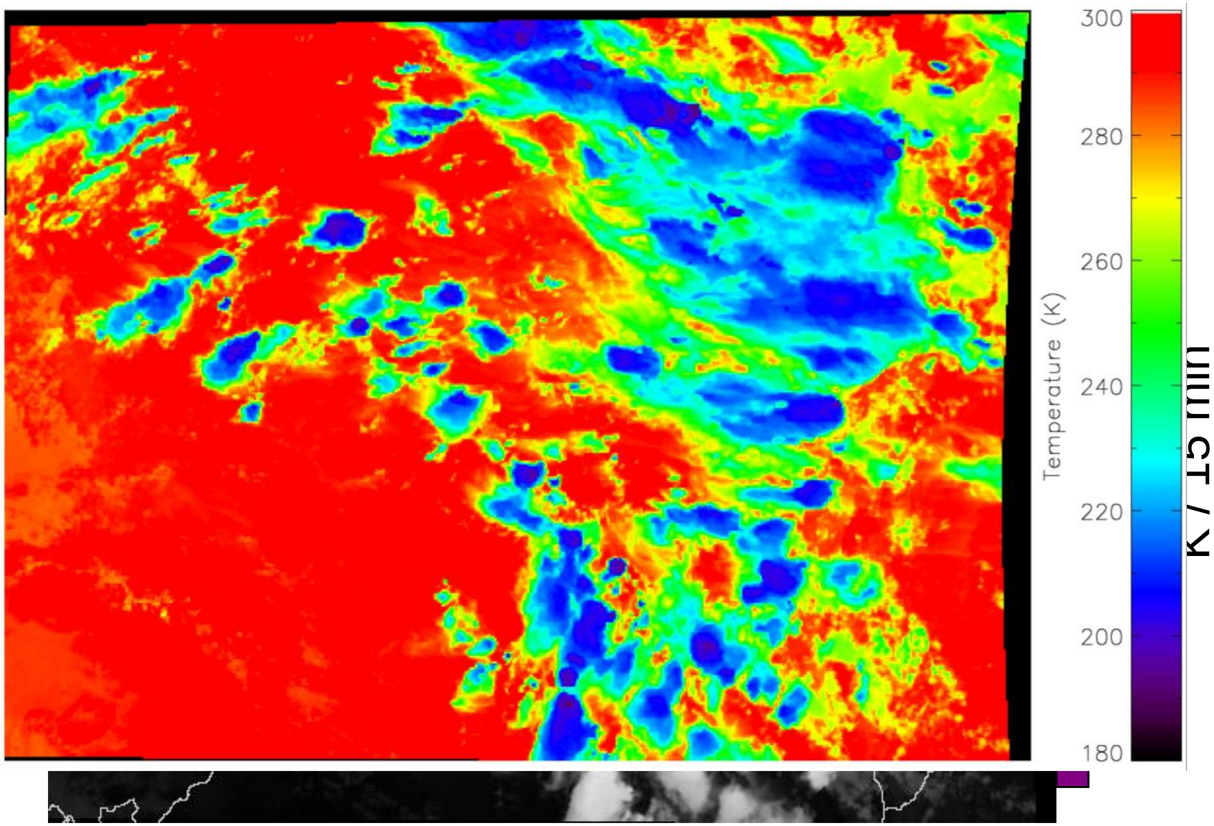


Overlap of anvils ≤ 213 K



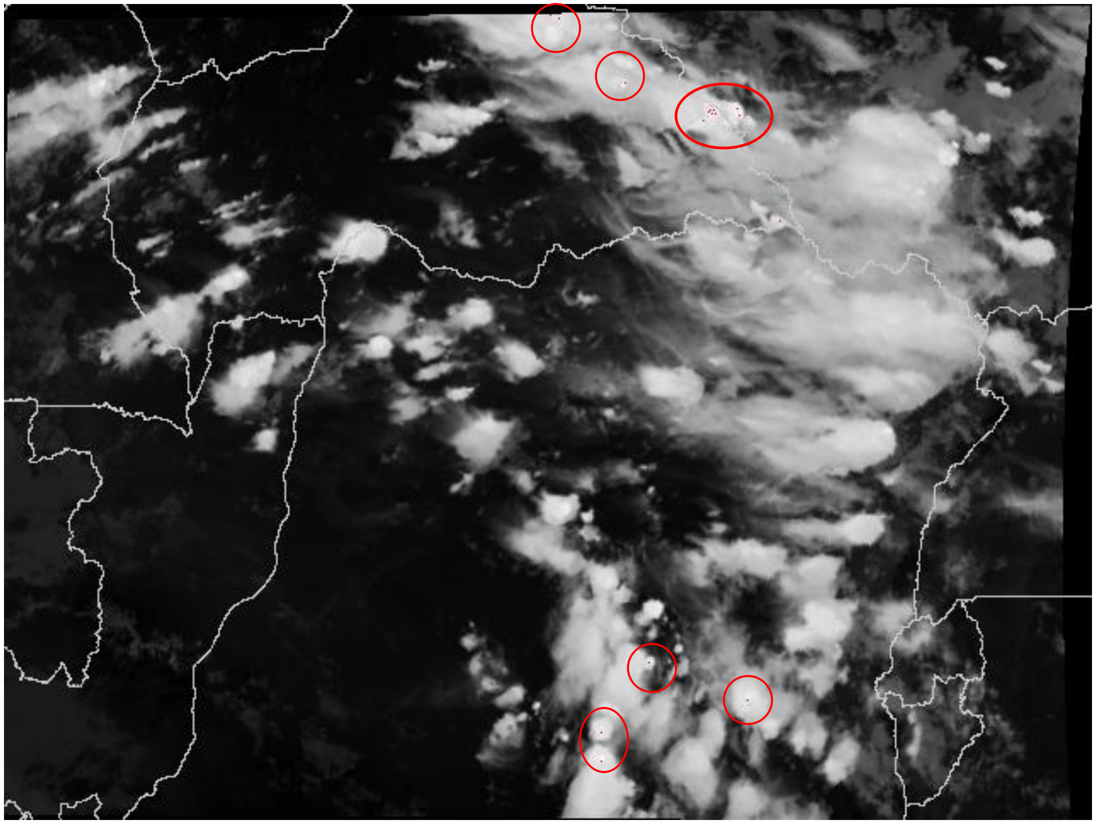
Cloud top Cooling Rate

- Where thunderstorms have not reached the tropopause or continue pulsing above the equilibrium level, cloud top cooling can be observed. The top 10% coldest pixels of each object are taken from time 1 to time 2 to calculate the cooling rate. Merged objects are omitted from this analysis.



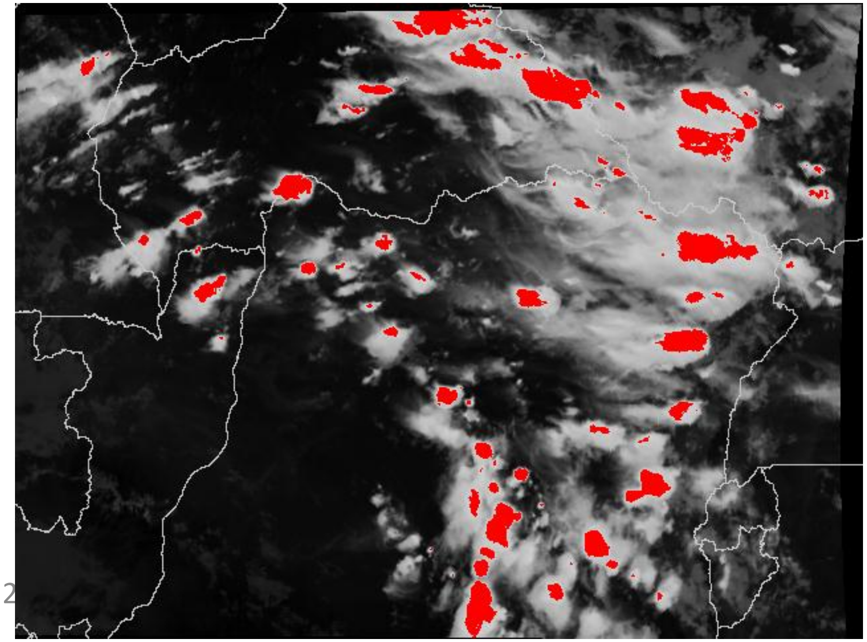
Overshooting Tops

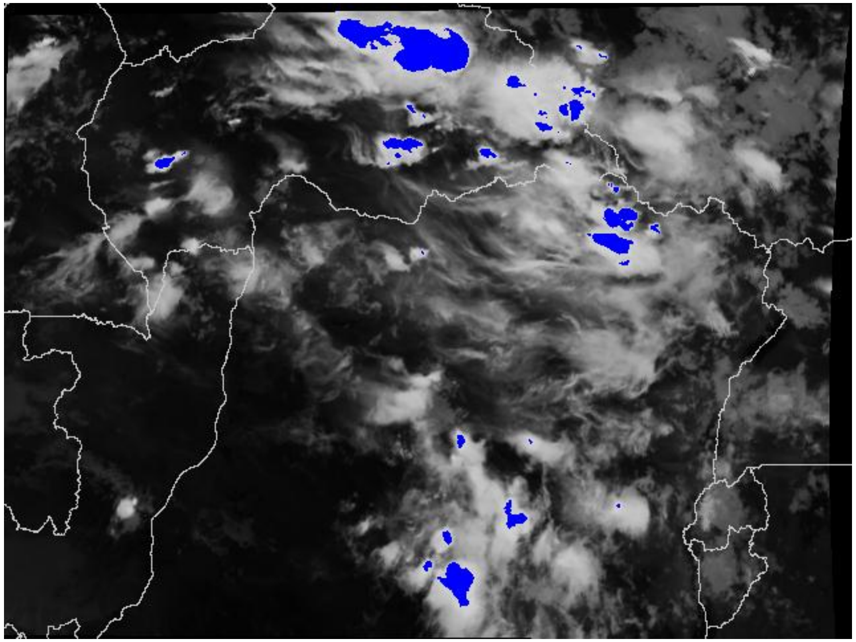
- Overshooting tops are an indication of a robust updraft that has enough momentum to penetrate the tropopause, yielding a bulge that can be seen in visible satellite imagery. Using the method developed by Mahovec et al. (2011), overshooting tops can be detected by using the water vapor (6.2 μm), total ozone (9.7 μm), and thermal IR (10.8 μm) channels.
  - Use of the 9.7 μm channel helps eliminate some of the false alarms produced by strictly using the 6.2–10.8 μm difference)
  - 6.2–10.8 μm > 3.5 K and 9.7–10.8 μm > 13 K



Storm Longevity

- Intense storms typically have an updraft that is able to maintain itself for a significant period of time rather than allow the downdraft or other mechanisms dilute the updraft.
  - Storms can be monitored over time to see if they maintain an anvil isotherm of 213 K that extends greater than some areal coverage (yet to be determined).
  - Most storms in the images have dissipated, yet a few still remain with large anvils associated with them (2 hours between images).



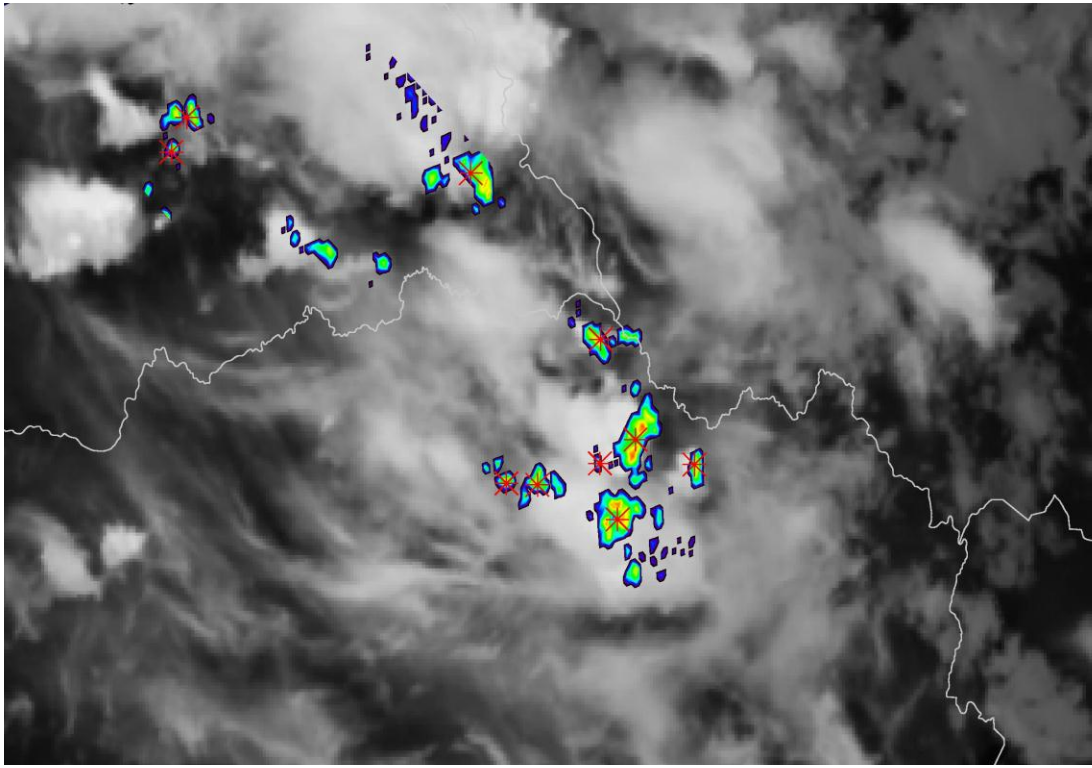


Ongoing Work

1. Combine TRMM intensity bins with MSG fields and LIS flash counts to determine a storm intensity estimate from MSG and LIS for all the intense storms as observed within the TRMM storm cell database (LeRoy and Petersen 2011).

1. Determine if intense open ocean convection behaves similarly to land convection in MSG imagery due to the lack of lightning in open ocean convection (i.e., can intensity be determined by MSG only).

1. Determine the feasibility of creating a potential hazardous weather aviation application.



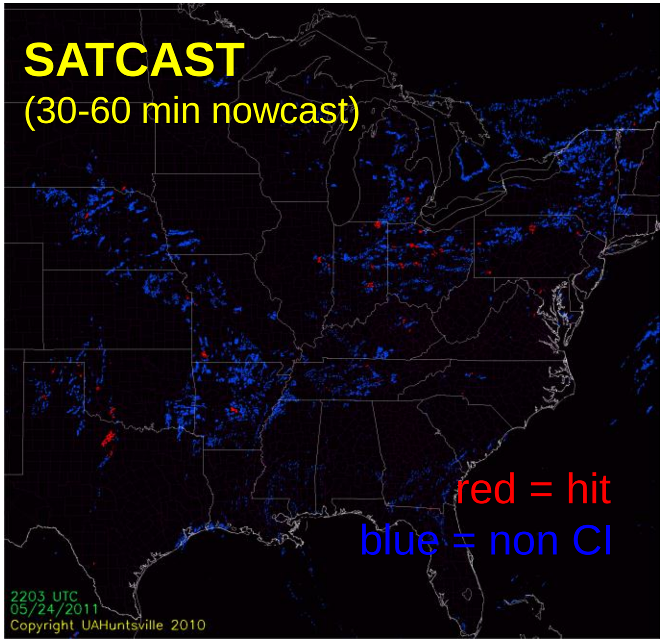
MSG IR imagery (1857 UTC) with TRMM PR near surface reflectivity (1851 UTC) and IWP location over-plotted on 1 August 2006.

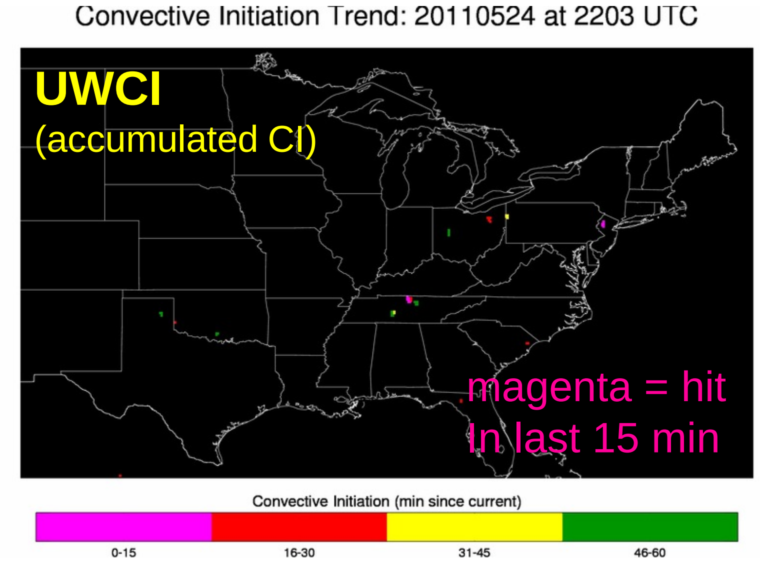
Outline

1. **Update GOES–R Storm Intensity Effort**
    a) Methodology
    b) Progress to date… and ongoing work

2. **Update on “Bake–off” towards PDSI**

Bake–off Comparison: SATCAST/UAHCI & UWCI





Status update… (mid September 2011)

- Difficulties in defining what CI is, between radar and satellite, stalled this evaluation from ~April through later August. CIMSS and UAH have helped Dr. V. Lakshmanan (CIMMS) get a better handled on how to perform the work.

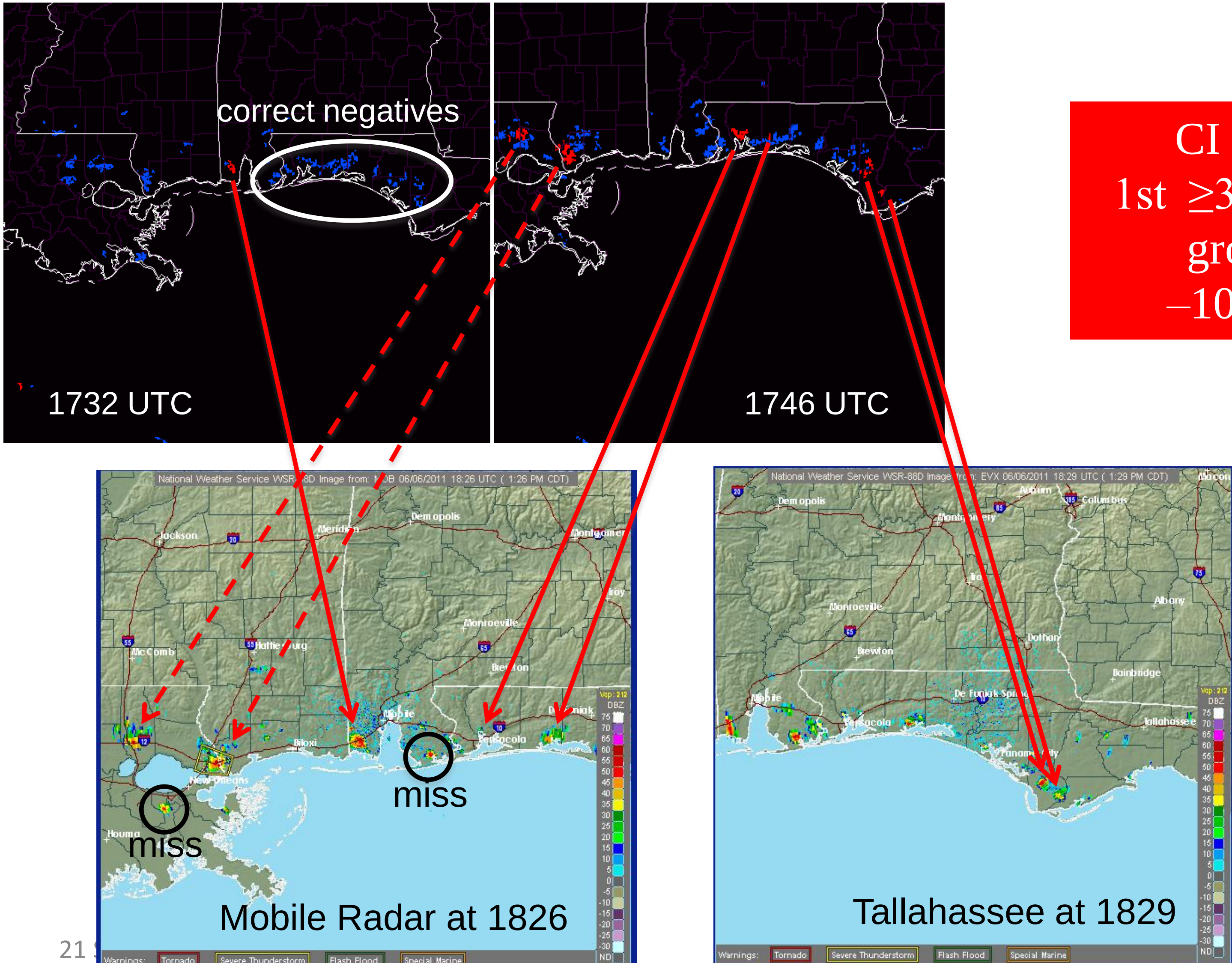
- Monthly teleconferences have kept both groups informed.

- Preliminary (albeit not deemed correct) results are for SATCAST having a POD=0.6, which the FAR for UWCI drops to ~0.30.

- Plan: Both UAH & CIMSS teams develop their assessment of a CI “hit,” “miss,” etc. and present to Dr. Lakshmanan as a means of knowing we are doing things correctly.

Methods: Convective Nowcasts/Diagnoses

SATellite Convection AnalySis and Tracking (SATCAST) System



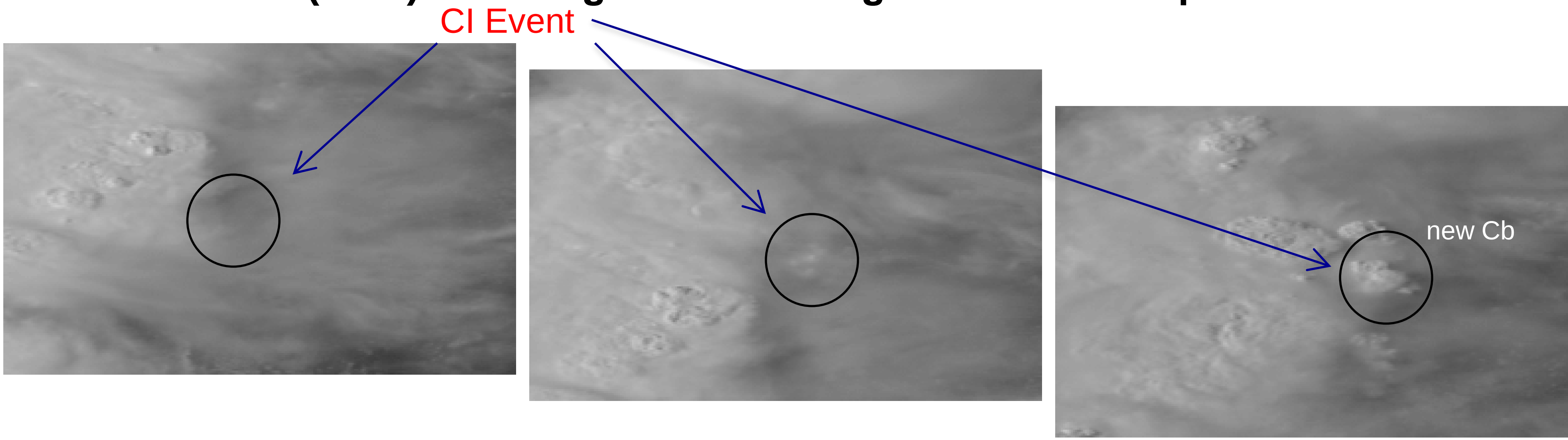
CI Definition:
1st ≥35 dBZ echo at ground, or at –10 ºC altitude

Walker et al. (2011)

Conclusions & Ongoing Research…

1. **Finalize Storm Intensity project; submit science paper.**

2. **Apply TSE and probabilistic nowcast methods in SATCAST (evaluate performance enhancements).**
3. **Seeking forecaster feedback... GOES-R HWT, OPC, AWT; NWS (testbed sites)**
4. **Mecikalski (2012) – Solving CI nowcasting beneath cirrus problems…**



5. **Use of thermal sharpening to optimize threshold scoring within SATCAST.**

Cumulus: 1 km^2 HRV overlaid onto 3 km^2 IR